RF Noise – What is it and what to do about it?

2015 Communications Academy

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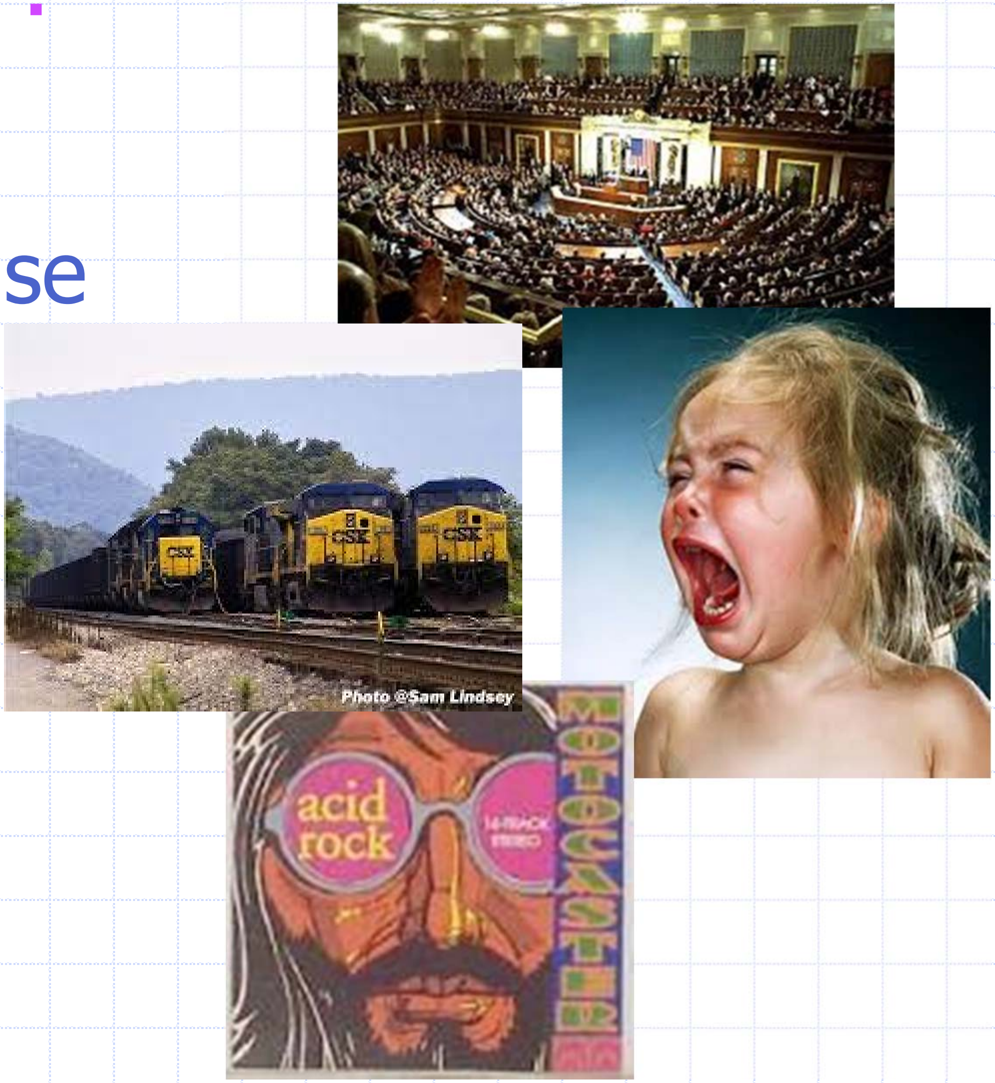
What is noise?

- Is it noise?
- One person's noise may be another person's signal

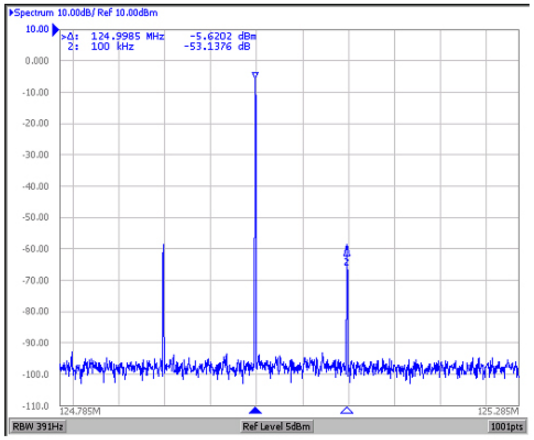


What is noise?

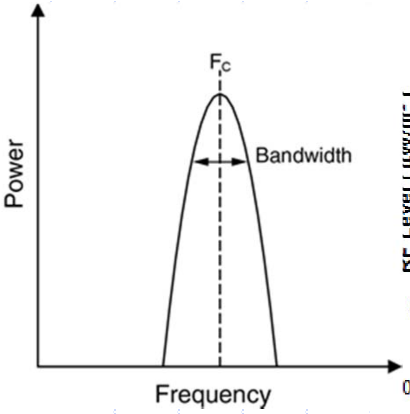
- Noise is any unwanted signal
- Discrete signals
  - Intermodulation
  - Adjacent channels
  - Harmonics
  - Spurs
- Random Signals
  - Thermal noise
  - Large number of discrete signals
  - Broadband modulation

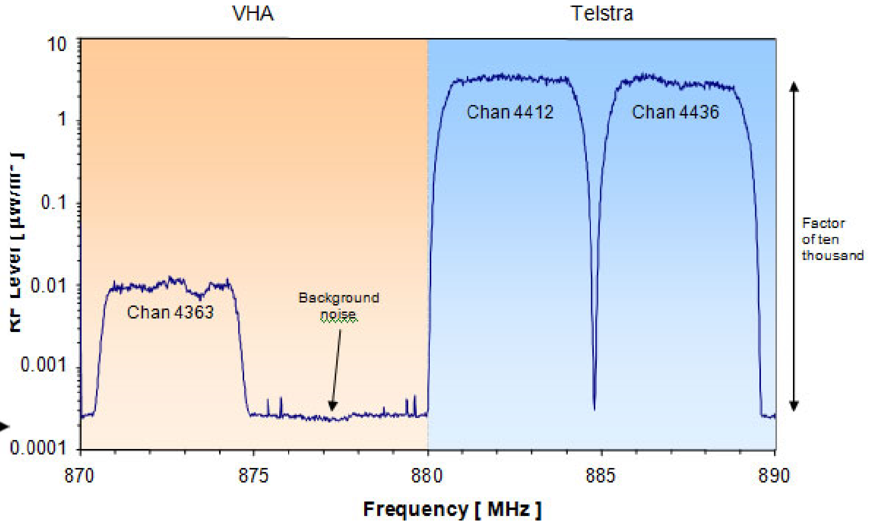
Noise Bandwidth

- Noise can affect both wideband and narrowband communications
- Wideband noise can affect narrowband communications
- Noise power is always a function of bandwidth
- High level wideband noise may result in a small amount of narrowband noise.



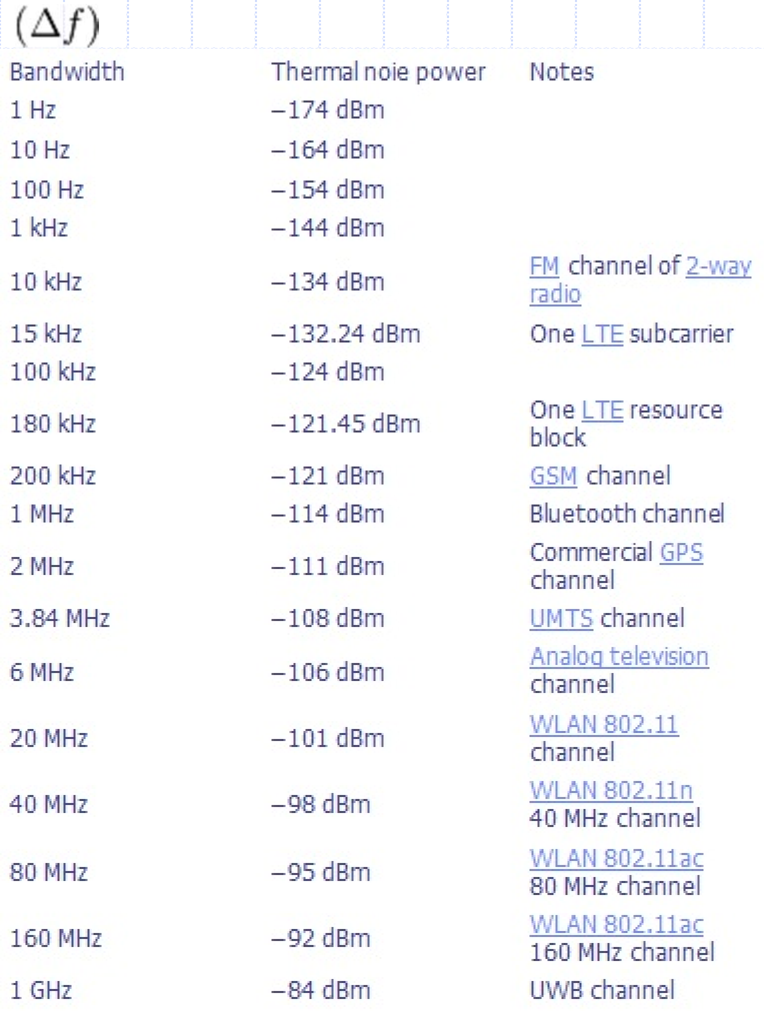
6. This power spectrum measurement was performed with the Agilent E5052.





How is noise measured?

- Measured at some specific bandwidth
  - Noise is generally measured as a power level but can also be measured as a voltage
  - Thermal noise defines the lowest noise level
  - Chart shows room temperature noise levels versus bandwidth



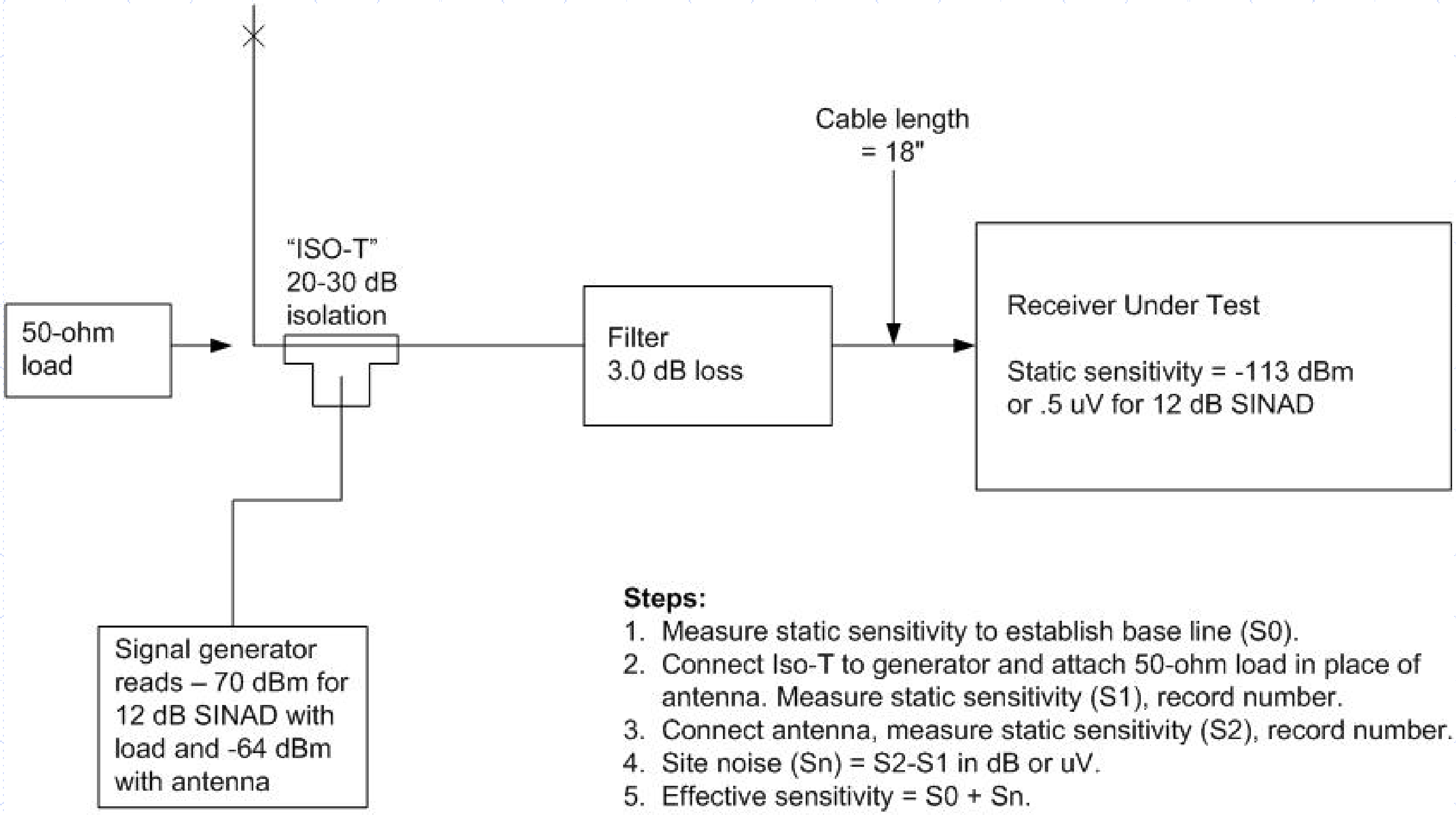
(Δf)

Bandwidth	Thermal noie power	Notes
1 Hz	−174 dBm	
10 Hz	−164 dBm	
100 Hz	−154 dBm	
1 kHz	−144 dBm	
10 kHz	−134 dBm	FM channel of 2-way radio
15 kHz	−132.24 dBm	One LTE subcarrier
100 kHz	−124 dBm	
180 kHz	−121.45 dBm	One LTE resource block
200 kHz	−121 dBm	GSM channel
1 MHz	−114 dBm	Bluetooth channel
2 MHz	−111 dBm	Commercial GPS channel
3.84 MHz	−108 dBm	UMTS channel
6 MHz	−106 dBm	Analog television channel
20 MHz	−101 dBm	WLAN 802.11 channel
40 MHz	−98 dBm	WLAN 802.11n 40 MHz channel
80 MHz	−95 dBm	WLAN 802.11ac 80 MHz channel
160 MHz	−92 dBm	WLAN 802.11ac 160 MHz channel
1 GHz	−84 dBm	UWB channel

How much noise?

- Narrowband noise
  - Hard to measure with a spectrum analyzer (SA)
    - Front end is broad so large "unseen" signals can cause measurement errors
    - SA noise floor usually higher than noise to be measured
    - SA receiver filters don't match actual receiver bandwidth
  - Best way is to use a relative measurement called effective receiver sensitivity.

Effective receiver sensitivity



50-ohm load

"ISO-T" 20-30 dB isolation

Filter 3.0 dB loss

Cable length = 18"

Receiver Under Test

Static sensitivity = -113 dBm or .5 uV for 12 dB SINAD

Signal generator reads – 70 dBm for 12 dB SINAD with load and -64 dBm with antenna

Steps:

1. Measure static sensitivity to establish base line (S0).
2. Connect Iso-T to generator and attach 50-ohm load in place of antenna. Measure static sensitivity (S1), record number.
3. Connect antenna, measure static sensitivity (S2), record number.
4. Site noise (Sn) = S2-S1 in dB or uV.
5. Effective sensitivity = S0 + Sn.

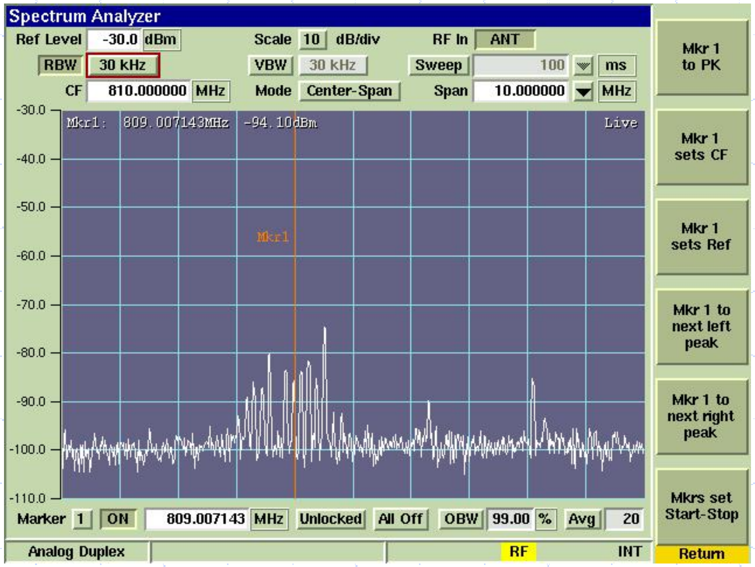
Effective Receiver Sensitivity = -113 dBm + 6 dB or -107 dBm

Narrowband noise

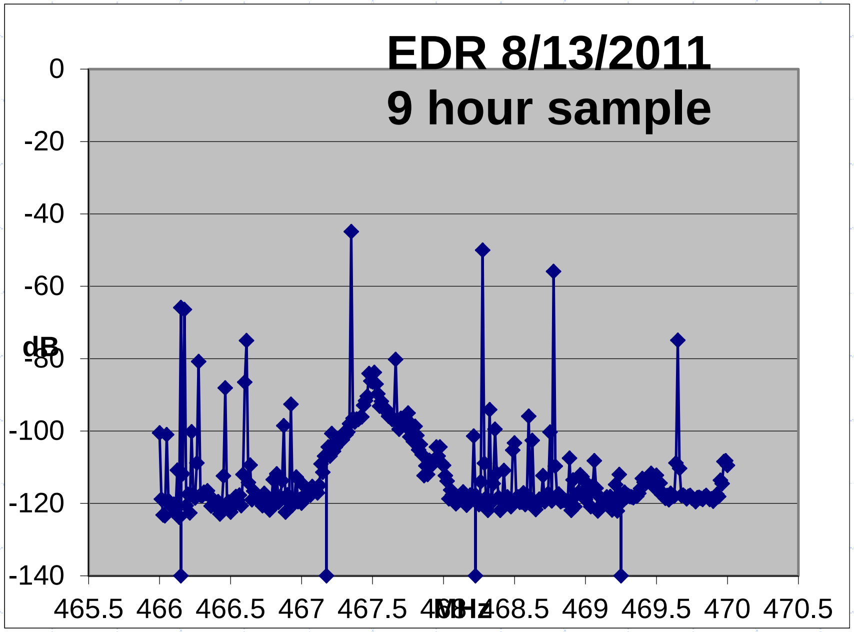
- What to expect (your mileage may vary)
  - Urban areas
    - Low-Band 20-40 dB
    - VHF 10-15 dB and often higher
    - UHF 5-10 dB and sometimes higher
    - 800 MHz 3-8 dB and sometimes higher
  - Rural areas
    - Low-Band 10-20 dB
    - VHF 6-10 dB and sometimes higher
    - UHF 3-8 dB and sometimes higher
    - 800 MHz 0-3 dB

Wideband noise

- Wideband "noise" affecting narrowband communications
- UHF was intermod with FM station
- 800 MHz was BDA gone bad

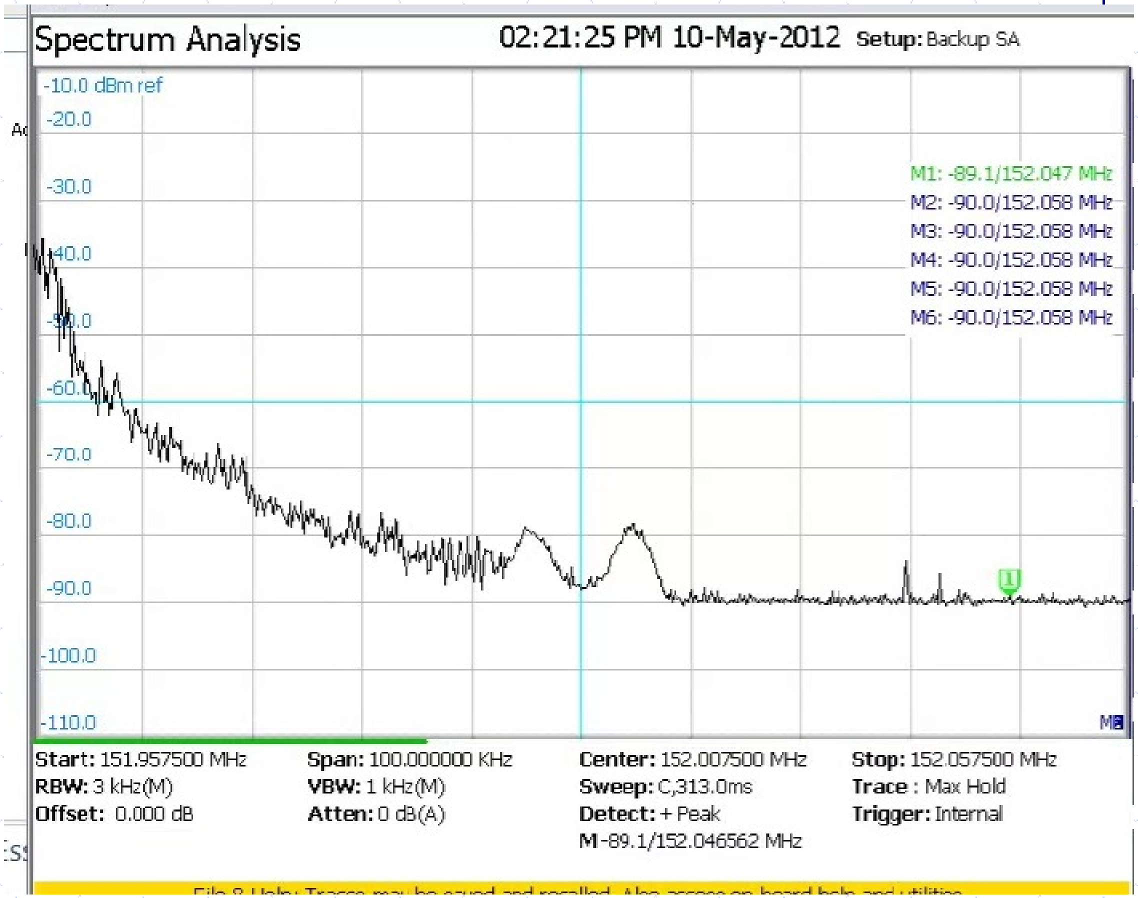

Spectrum Analyzer

Ref Level -30.0 dBm
Scale 10 dB/div
RF In ANT
RBW 30 kHz
VBW 30 kHz
Sweep 100 ms
CF 810.000000 MHz
Mode Center-Span
Span 10.000000 MHz
Mkr1: 809.007143MHz -94.10dBm
Marker 1 ON 809.007143 MHz
Unlocked
All Off
OBW 99.00 %
Avg 20
Analog Duplex



Close-in noise

- Note noise levels closer to left edge caused by nearby transmitter
- Note also noise floor of SA at -90 represents lowest signal that can be received



Spectrum Analysis 02:21:25 PM 10-May-2012 **Setup:** Backup SA

M1: -89.1/152.047 MHz
M2: -90.0/152.058 MHz
M3: -90.0/152.058 MHz
M4: -90.0/152.058 MHz
M5: -90.0/152.058 MHz
M6: -90.0/152.058 MHz

Start: 151.957500 MHz
RBW: 3 kHz(M)
Offset: 0.000 dB
Span: 100.000000 KHz
VBW: 1 kHz(M)
Atten: 0 dB(A)
Center: 152.007500 MHz
Sweep: C,313.0ms
Detect: + Peak
M -89.1/152.046562 MHz
Stop: 152.057500 MHz
Trace : Max Hold
Trigger: Internal

Noise Combat

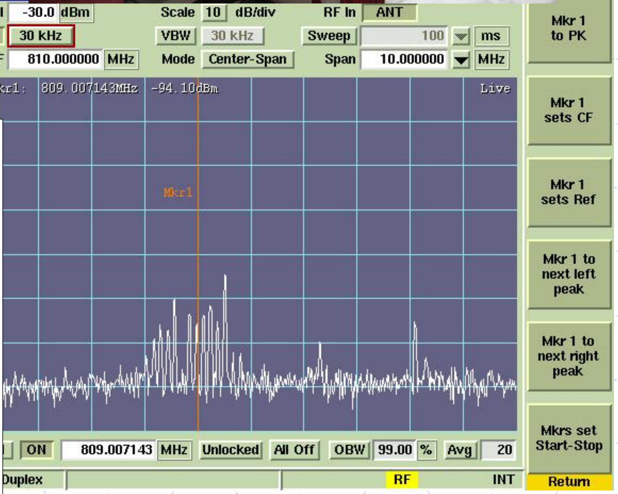
- Know the enemy
  - Where is the noise being generated?
    - In the receiver?
    - Co-channel
    - Non-co-channel
    - Single transmitter
    - Other devices
    - Everywhere
  - What type of noise is it?
    - Modulation or carrier
    - Wideband
    - Broadband
    - Intermodulation

Inside or outside

- First determine if the noise is generated in your local receiving system or outside
  - If inside, solution is to do something with the receiver
    - Filters
    - Attenuation
  - If outside, solution is to do something at the noise source
    - Transmitter filters
    - Turn off source
    - Change frequency
    - Clean up site

Finding the noise

- Track it down using deductive process
  - – Direction finding
  - – Time of day or event related?
  - – Frequency related
  - – Turn things on and off
  - – Nature of the spectrum



Spectrum Ar

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RF In ANT
RBW 30 kHz
VBW 30 kHz
Sweep 100 ms
CF 810.000000 MHz
Mode Center-Span
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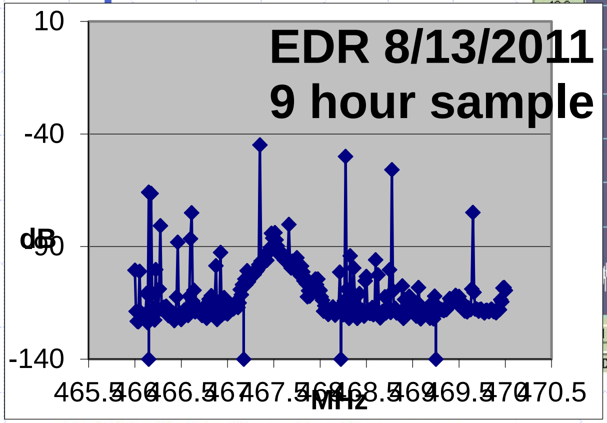
ON 809.007143 MHz Unlocked All Off OBW 99.00 % Avg 20

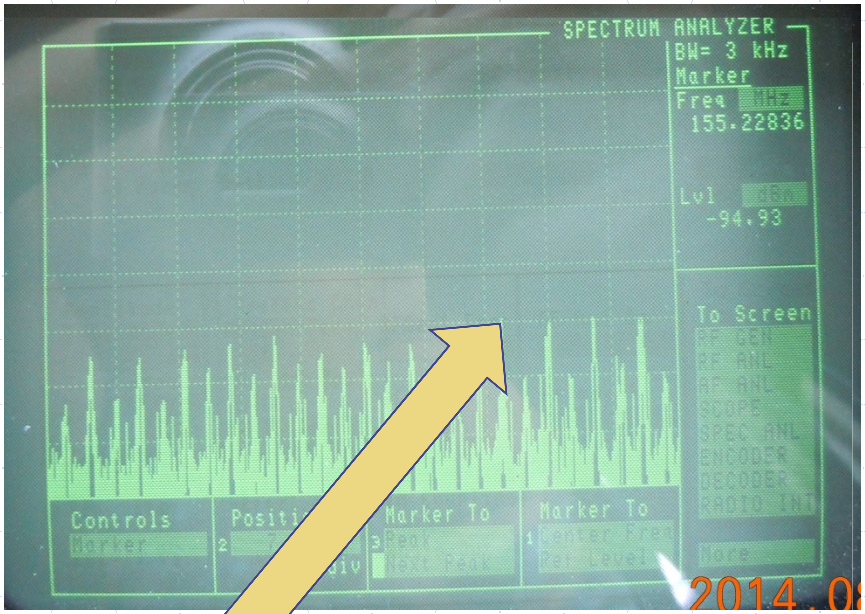


Finding the noise

- Know your test equipment
  - What is the noise floor?
  - How do the VBW, RBW, and sweep time affect the display of various kinds of signals?
  - Use an external pre-amp or not. If so, understand its limitations
  - Use of additional filters with the test equipment
  - SA sensitivity likely not high enough to find 10 dB of noise. External pre-amp may be required. Angle Linear has several good pre-amps. High 3rd order intercept is more important than low noise.

Finding the noise

- Make sure you understand your test equipment
- Resolution bandwidth for your test equipment most likely will not match your receiver.
- Adjust SA reading to receiver bandwidth.
- Double the bandwidth double the noise.



-80 dBm in 3 kHz BW

Finding the noise

- Noise can come from just about anywhere even at higher frequencies.
  - Power line insulators at VHF
  - TV antenna amplifiers at UHF and 800 MHz
  - Computers (everything has computers) at VHF and UHF, use of clock jitter has masked the problem
  - GE lighting ballasts at 700 MHz LTE
  - Diodes in equipment exposed to higher RF levels
  - Site junk, bad RF connectors, broken antennas
  - Plus all the usual suspects of bad amplifiers, etc.

Receiver Desensitization

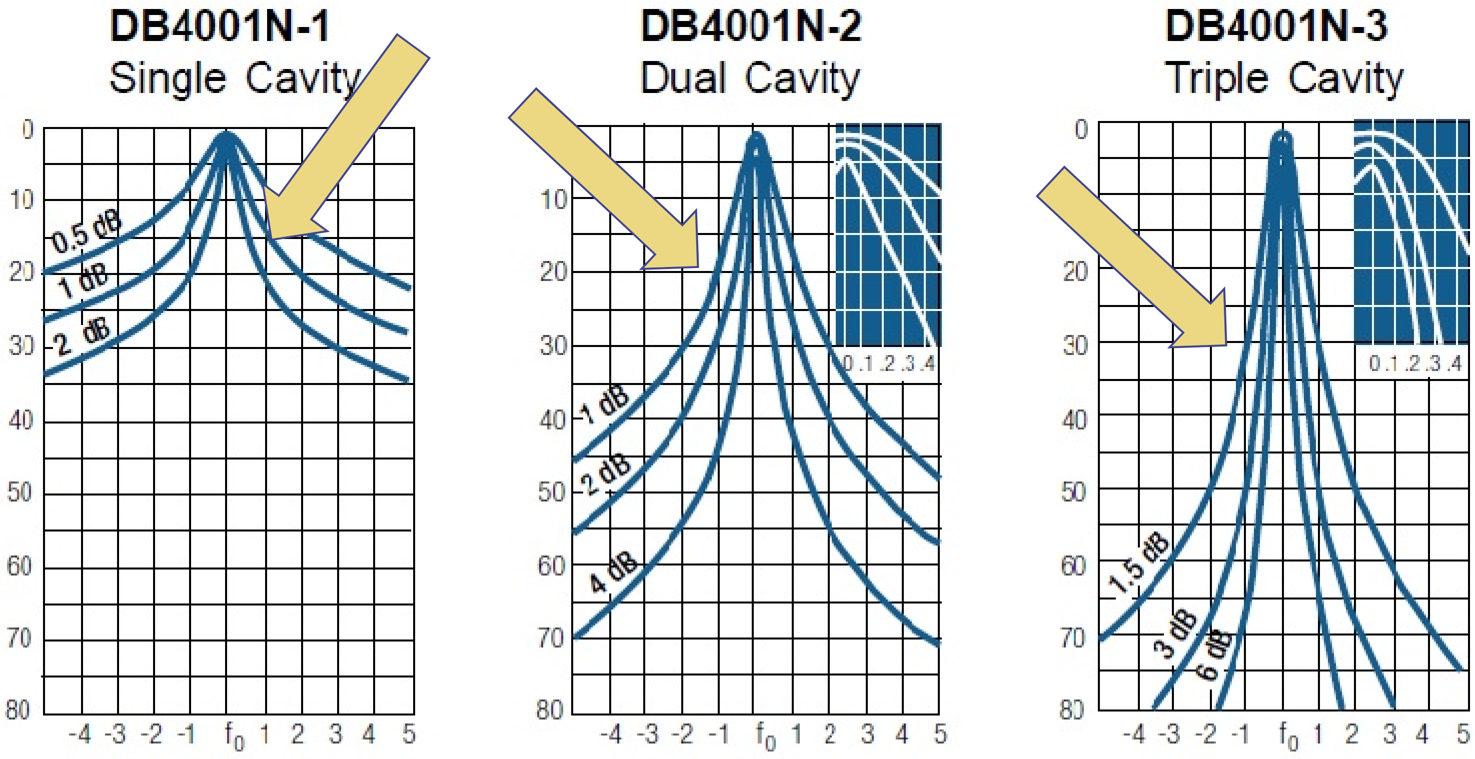
- Not really a “noise” problem but can result in reduced receiver sensitivity.
- Caused by high nearby signal causing the receiver amplifiers to go into compression
- Most commercial receivers have input signal limits of around -35 to -20 dBm
- Test by putting a 6 dB attenuator in the receive antenna line and determine if the interference is reduced by greater than 6 dB. If so, interference is likely receiver desense.
- Some type of receiver RF filter is usually required. Sometimes, just the attenuator fixes the problem.

Receiver Interference Fixes

- Receiver Intermod
  - Better filtering – add a cavity
  - Reduce input signal – add an attenuator
  - Better receiver
- Inadequate spurious rejection
  - Better filtering – add a cavity
  - Better receiver

Receive Performance – Selectivity

- Bandwidth versus loss gets better with more cavities



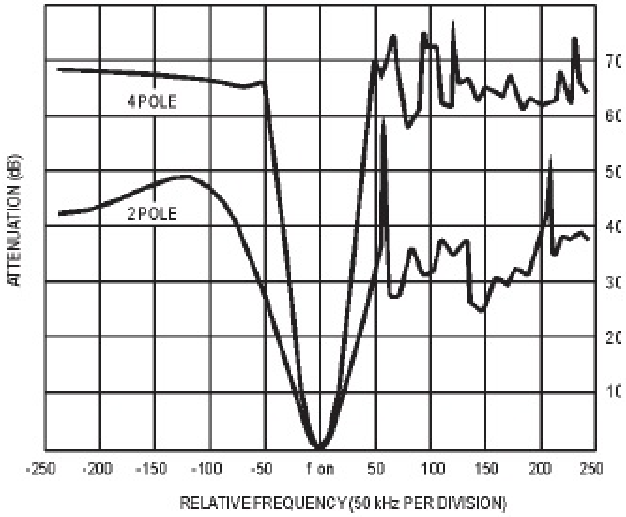
Receiver Interference Fixes

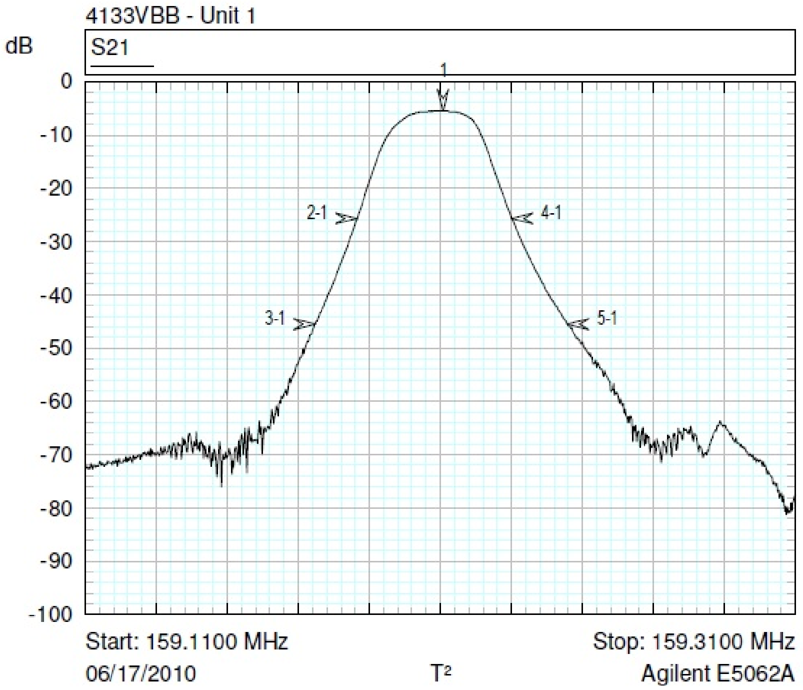
- Inadequate adjacent channel rejection
  - Add a crystal filter (not at 450 or 800 MHz)
  - Modify frequency plan
  - Change antenna
  - Better receiver
- Receiver desensitization
  - Reduce interfering signal
    - Add cavity
    - Move antenna
    - Pins in transmitter coax?
    - Lower transmitter power

Receiver Performance - Selectivity

- Crystal filters can provide protection at both the RF and IF level

TYPICAL RESPONSE CURVES





Mkr	Trace	X-Axis	Value	Notes
1	S21	159.2108 MHz	-5.5537 dB	
2-1	S21	-24.1457 kHz	-20.0000 dB	
3-1	S21	-36.1157 kHz	-40.0000 dB	
4-1	S21	19.3482 kHz	-20.0000 dB	
5-1	S21	34.9859 kHz	-40.0000 dB	

Receiver Interference Fixes

- External intermod
  - Find source of intermod
  - Move transmitter or receiver antennas
  - Modify frequency plan
- Transmitter noise
  - Add cavity to transmitter, might need a notch on the receive frequency
  - Move/change antenna
  - Check transmitter alignment
  - Check transmitter antenna

RF Noise Fixes

- Sometimes there is nothing one can do. The fix is too complex for anyone to fix.
- ISM equipment may be operating legally
- Lots of information from ARRL and others about using ferrite beads, etc. to help stop interference.

- Test electronics before installation to determine if they will cause interference
- Call the FCC if level is bad enough

Questions?

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